

A Wavemeter for the Frequency Range 23.5 to 24.5 GHz

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The wavemeter for the 1.5 cm amateur band to be described in this article is based on an older, American publication (1). This wavemeter exhibits a high resolution and excellent reproducibility of the calibration. Due to its construction, the wavemeter is insensitive to temperature fluctuations. However, the construction requires some mechanical skill, and access to a lathe with threading capabilities.

This article is firstly to describe the electrical fundamentals; the mechanical details regarding construction are limited mainly to the resonance chamber with tuning pin, and critical dimensions are to be underlined. No calibration scale is described, since there are many methods of doing this. It is possible, for instance, to use a micrometer screw or another form of drive — the author uses a home-made micrometer screw. The usual, decadic division

was marked on this screw with the aid of a semicircle, and the coarse division is marked on the spindle case. The mechanical stability is not perfect due to the short threaded guide (play).

TECHNICAL DESCRIPTION

Most X and K-band wavemeters described for home construction usually work according to the self-calibrating principle (2), (3). The waveguide wavelength λ_H can be calibrated from the inner dimensions of the waveguide and the (hopefully) known and present wave mode. This is then measured and recalculated to the free-space wavelength λ_0 , and finally to the frequency to be measured after considering the waveguide values.

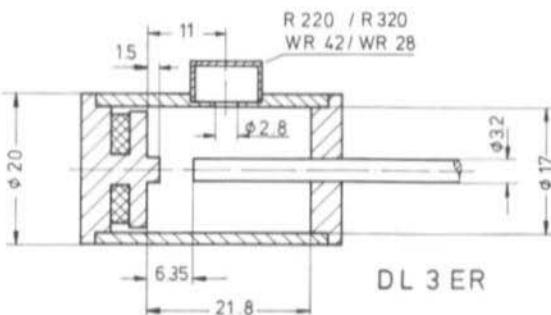


Fig. 1:
Principle of operation,
and critical dimensions
of a wavemeter

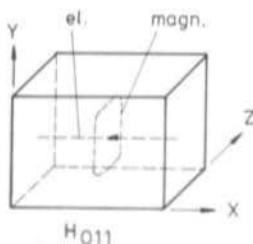


Fig. 2:
Characteristics of the electrical and magnetic lines of field of a H_{011} -mode

The disadvantage of this simple wavemeter – immaterial whether it is coaxial or waveguide – is its unfavorable tuning ratio $\Delta f/\Delta l$. This means a small variation of length Δl will cause a relatively large frequency change Δf . This results in a noticeable temperature dependence, and errors during the measuring process.

The construction to be described virtually avoids these disadvantages, since the tuning length amounts to approximately 8 mm for a frequency variation of 23.5 to 24.5 GHz.

However, an accurate frequency source must be available for calibration.

The wavemeter operates with wave mode TE_{011} (also called H_{011}) in a cylindrical cavity resonator. As can be seen in Figure 1, the frequency to be measured is coupled in from the waveguide via an iris. The resonance frequency is increased on inserting the tuning

pin. It only causes a slight field distortion, which results in a small $\Delta f/\Delta l$. In addition to this, the Q is very high, and is in the order of approximately 5000 to 6000 in the case of the loosely coupled resonator, if all components are silver-plated.

The system is designated as a hybrid due to its partial, coaxial construction. Since radial currents are present in the terminating panels with the TE_{01} wave mode for both coaxial and cavity resonators (see Figure 2), it is possible for the tuning pin to be inserted through a central cutout without terminating choke or contact finger, and with a gap spacing of approximately 0.1 to 0.15 mm. Opposite to the tuning pin the cavity resonator is terminated using a choke-system, that is filled with lossy material. This is provided to avoid higher, unwanted wave modes. The protruding end of the choke opposite to the tuning pin is in the form of a small cylinder (4 mm dia., 1.5 mm long), as shown in Figure 7. This linearizes the tuning curve at the highest frequency (fully inserted).

CONSTRUCTION

The dimensions given in Figure 1 are the critical dimensions, and must be maintained as accurately as possible. They are valid for all 3 types of waveguide that can be used (4).

Figure 3 shows the construction and gives all dimensions. The individual parts are given in the following drawings.

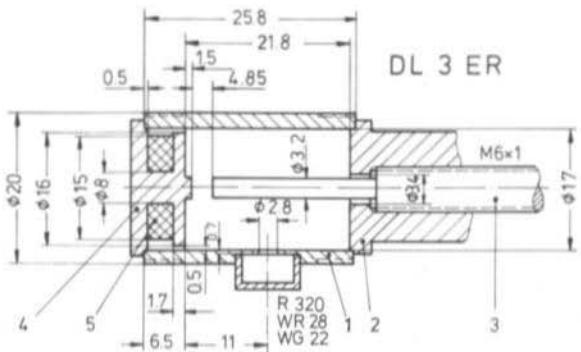


Fig. 3:
A micrometer satisfying
the requirements is fitted
to Part 2 and Part 3

The cavity resonator (Part 1, **Figure 4**) is made from a brass tube of 20 mm x 1.5 mm. This is cut exactly to the required length, and provided with a thread of M 20x1. This is the same threading as used for the well-known »spinner plug« 3.5/9.5. The choke holder (Part 4) and the cover with threaded bushing (Part 2) are screwed together using such nuts. The cover (**Figure 5**) and also Part 4 are provided with a crimp and are fitted without play into the resonator chamber (Part 1). A slight play can be compensated for if necessary by using a galvanic, silver-plating.

The tuning pin (Part 3, **Figure 6**) is held firmly in the very long thread in Part 2. A temperature-stable grease can be provided to ensure a smooth run, however, attention must be paid that no grease can penetrate into the resonator chamber.

A material (Part 5) is glued into the choke holder (Part 4, **Figure 7**) that exhibits a large loss at microwave frequencies. Suitable materials are pertinax, bakelite, plastic materials containing graphite, or a special microwave-absorption foil.

The width of the milled slot in Part 1 is dependent on the waveguide to be used. The author used waveguide R 320/WR 28. The position and diameter of the iris cutout are independent on the type of waveguide. A dip of approximately 40% results when using the described iris.

A wide side of the waveguide is removed; the size is dependent on the flat surface of the resonator, which means that the resonator replaces the walling of the waveguide. Waveguide and resonator are soft-soldered together at the end of construction. Residual solder and flux should be carefully removed afterwards.

The calibration scale depends on the possibilities and requirements. In the case of the author's prototype, Part 3 is provided with a home-made micrometer screw head in which a division of 0 to 90 in steps of ten, with a subdivision in »half steps of ten« has been marked. Part 2 is provided with the corresponding, linear millimeter division.

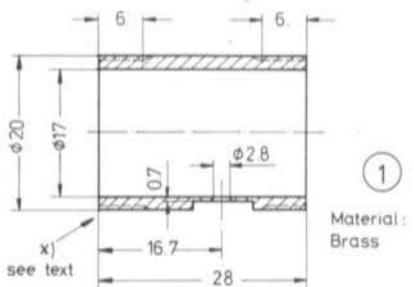


Fig. 4:
The two threads x must fit the required nuts;
the milling must suit the waveguide to be used

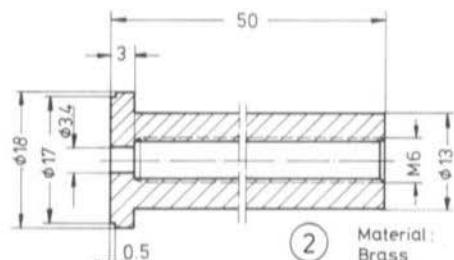


Fig. 5:
Part 3 should be held virtually without play
by the long M 6-thread

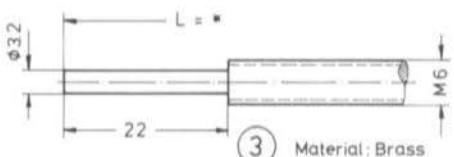


Fig. 6:
The extension to the right is dependent
on the micrometer used

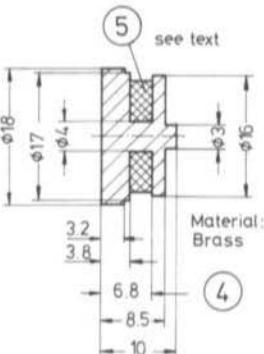


Fig. 7:
The choke attenuates unwanted wave modes
using a lossy material (Part 5)

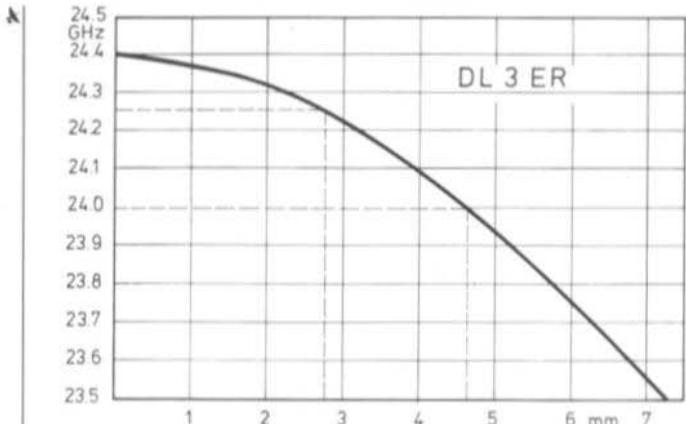


Fig. 8:
Tuning range of the
author's prototype
wavemeter

Part 2 can also be modified for accepting an available depth-micrometer, which, of course, means that modifications must be made to Part 3.

However, the 24 GHz amateur band is in the range of 24.0 to 24.250 GHz, which is still covered in a virtually linear scale with a tuning range of approximately 2 mm.

CALIBRATION OF THE WAVEMETER

As has been previously mentioned, an accurate-calibration oscillator, or an oscillator together with another, exactly calibrated wavemeter is required for calibrating the home-made wavemeter. The resonance frequency dip is now sought with the aid of a connected, detector probe. This is repeated for the whole frequency range, and the result is a calibration curve similar to that of the author's prototype shown in **Figure 8**.

However, the author's prototype is somewhat too long due to tolerances in the resonator chamber. Furthermore, the cylinder on Part 4, which should be 1.5 mm long, is also missing. For this reason, the calibration curve is somewhat bent towards the high-frequency end.

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